RESOURCE CONSTRAINING

APPENDIX B

PROCEDURES

When daily equipment and personnel requirements exceed what is available to the manager for a project, he must *resource constrain* the project to have as little effect as possible on the project duration. Often resources can be shifted in such a way to avoid delaying the overall project duration; however, shifting resources may result In more critical activities and certainly less available float of some activities within the ES schedule.

Resource constraining a project consists of three parts: 1) resource constrain the ES schedule, 2) update the logic network, and 3) update the ES schedule.

PART 1: RESOURCE CONSTRAIN THE EARLY START SCHEDULE

Step 1. Find the first time period where resource requirements exceed the resources allocated. ES schedule resource manipulation must be done chronologically, one time period at a time, working from left to right within the ES schedule.

Step 2. Choose an activity(ies) to delay. In order to solve the problem of too many scheduled resources on a given day, you must delay an activity from being done and consuming resources on that day. To select which activity would be the best to delay, consider the following five priorities.

- The first priority choosing which activity to delay is to choose an activity that starts on the time period resources are exceeded. By choosing to delay an activity that has already started and is on-going, you are leaving that job undone, pulling out the resources, and planning to come back to finish it later. Choosing an activity that is just scheduled to start saves start-up and shut-down time, as well as unnecessary transportation requirements and extra on-site material-delivery coordination and security. If more than one activity is scheduled to start on the time period resources are exceeded, then consider the next priority for determining which activity to choose to delay.
- The second priority for choosing which activity to delay is to choose an activity that, when delayed, provides sufficient resources to solve the constraint problem. For example, if you have 15 trucks scheduled for a particular day but have only 12 trucks available to use, delaying an activity that uses just 2 trucks does not solve your problem; you now have only 13 trucks scheduled for that day, but you need to constrain it down to the 12 trucks (or less) that you have available. Choosing to delay an activity that uses, for example, 5 trucks on that day will bring your scheduled total down to 10, which solves the problem on that day. If no single activity provides sufficient resources to lower the amount to or below what you have available, then choose a combination of activities to delay to meet the constraint requirement. If, however, more than one activity provides sufficient resources to solve the problem, then

consider the next priority for determining which activity to delay.

- The third priority for choosing which activity to delay is to choose an activity with the most total float. This will prevent the manager from selecting critical or nearly critical activities to delay, unless absolutely necessary. If more than one activity has the most total float, (for example, three activities each have six days total float), then consider the next priority for determining which activity to delay.

- The fourth priority for choosing which activity to delay is to choose an activity with the most free float. Activities with more free float are less likely to impact follow-on activities in the schedule. If more than one activity has the most free float for example, two activities each have four days free float of the six days total float), then consider the next priority for determining which activity to delay.

  The fifth priority for choosing which activity to delay is to choose the activity with the shortest activity duration. Shorter activity duration estimates are less likely to be incorrect and to extend the project's overall duration.

Step 3. Delay that activity one time period and follow the delay through the schedule. If an activity is delayed into interfering float or past its right bracket (LF), follow the results of the delay through the rest of the schedule. (An activity delayed into interfering float will delay another activity but will not delay the project duration.)

- Identify all activities that logically follow the delayed activity. The numbers of the follow-on activities are shown in parentheses behind the number of the delayed activity (those activities that cannot begin until the delayed, dependent activity is complete). For example, activity 25(40,55) indicates that activities 40 and 55 logically follow activity 25, and they may or may not be affected by the delay of activity 25. Check each of these follow-on activities to see if its ES time precedes the new EF time of the recently delayed activity. If so, delay that follow-on activity's ES until the first time period after the EF of the activity which had been delayed for resources. Subsequently, check activities 40 and 55 and the follow-on activities of 40 and 55 for possible effects. This pattern continues until all conflicting follow-on activities are delayed into free float.

Step 4. Sum the resources. After following the delay through the schedule, determine the new total resource requirement for each time period.

Step 5. Proceed to the next time period. Move to the next time period where required resources exceed the resources available. Repeat steps 2 through 4 above until the entire schedule has been adjusted to meet the resource limitations.

Step 6. Identity the cause of the delay. If an activity was delayed for resources at any time, place an "R" to the right of its LF bracket (see Figure B-1). If an activity was delayed because of logic only (because it logically follows a previously delayed activity), place an "L" to the right of its LF bracket. If an activity was delayed for both resources and logic (for example, an activity which was logically delayed because of a resource-delayed activity and then later further delayed because, of resources), mark the activity as a resource delay.

Step 7. Draw the resouree flow arrow(s). Each resource-delayed activity is immediately preceded by an activity(ies) that uses the same resource and has an EF time that is one time period before the resource-delayed activity begins. This activity(ies), when coupled with "mothballed" resources, will often provide sufficient resources to start the work the next time period. "Mothballed" resources are resources that were not put to work in the previous time period. (For example, 2 trucks were "mothballed" the day that 12 trucks are available and only 10 trucks were scheduled for work.) If two or more activities that use the same resource are scheduled to finish (EF) during the preceding time period,

choose the one which, when coupled with "mothballed" resources from the previous time period, will provide the least suffient resource; in other words, avoid resource overkill. Draw a resource flow arrow(s) from the end of the activity providing the resources to the beginning of the resource-delayed activity. If no one activity can provide sufficient resources, even when coupled with "mothballed" resources that were not in use during the previous day, draw flow arrows from two or more ending activities to the start of the resource-delayed activity.

Figure B-1 is resource constrained down to 18 carpenters. Now activity 15(50) is resource-delayed and will begin on time period 5.

Look at the preceding time period (4) for activities that end there and that use the same type of resource. Both activities 5(60,65) and 10(70) end at time period 4, but only activity 10(70) provides sufficient resources for activity 15(50) to begin. Therefore, activity 10(70) must be completed before activity 15(50) can begin. In this example, draw a resource flow arrow from the scheduled end (EF) of activity 10(70) to the new beginning (ES) of activity 15(50).

An activity may require assets from two or more activities, or one activity may provide assets for two or more activities. Figure B-2 is resource constrained down to 14 scoop loaders.

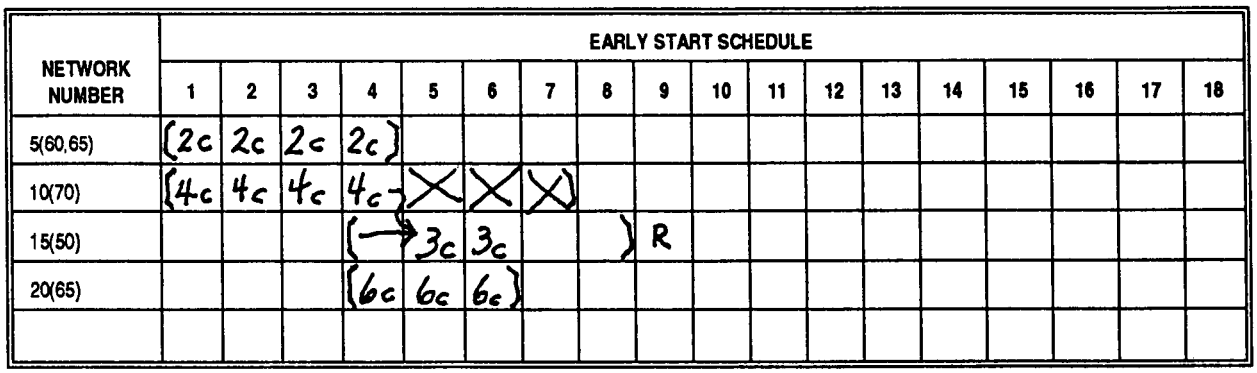


Figure B-1. Resource flow arrow

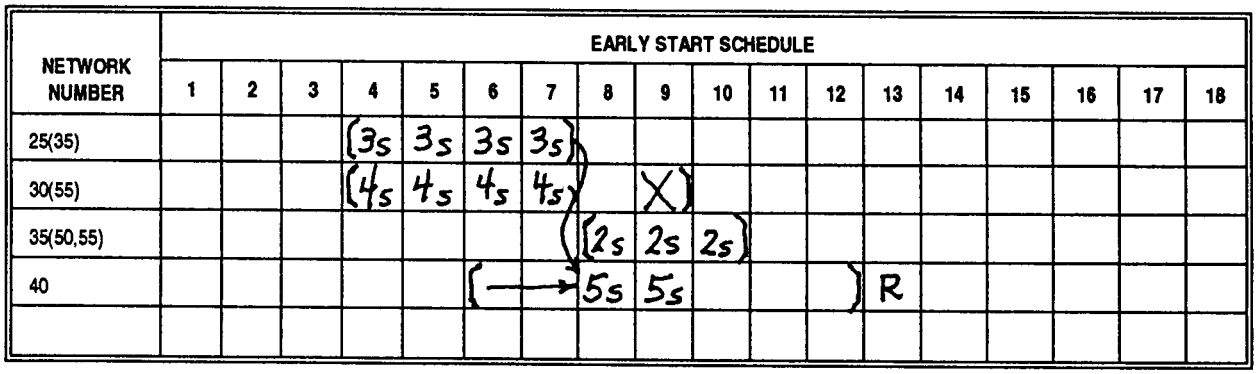


Figure B-2. Multiple resource flow arrows

Activities 25(35) and 30(55) are both necessary to provide sufficient resources for activity 40 when coupled with two of the three unscheduled "mothball" resources not used in time period 7.

PART 2: UPDATE THE LOGIC NETWORK

Step 8. Draw the resource dummy arrow. A resource dummy arrow must be added to the logic network for every resource flow arrow on the ES schedule. Draw the resource dummy arrow from the activity(ies) that provide the resources to the activity(ies) that receive the resources. In Figure B-3, activity 20 provides resources for activity 30. It is not necessary to maintain the activity numbering rules (lower to higher) when adding resource dummy arrows.

Step 9. Conduct a new time analysis. Treat the added resource dummy arrow as a logic arrow, and conduct new forward and backward passes. The resource dummy arrow will change some of the early and late starts and finishes of the nodes in the network, and it may cause a change or addition to the critical path(s).

PART 3: UPDATE THE EARLY START SCHEDULE

Step 10. List activities. Activities that provided resources will gain new follow-on activity numbers (in parentheses).

Step 11. Mark time frames. Check the ES and LF times in the network for all activities. If an activity's ES or LF changed, remark the left and right brackets accordingly.

Step 12. Identify float. Recalculate interfering float for each activity based on the new ES and LF times. Update the interfering float ("Xs") on the ES schedule.

This step-by-step procedure will provide a solution to the problem of insufficient numbers of resources. If this technique results in project delays that are unacceptable, there are variations the manager can use to select activities to delay.

The first variation is to delay an activity that has already started by splitting the activity. This option requires that you essentially make two activities out of one and redefine the logic network. You must remember to add the new activity to the ES schedule.

The second variation often provides the better solution to the resource problem. It is to delay an activity that is scheduled to begin **before** the time period in question. The delay procedure used is the same, except that the activity delay will be greater than one time period; therefore, plenty of float is required for that activity's delay.

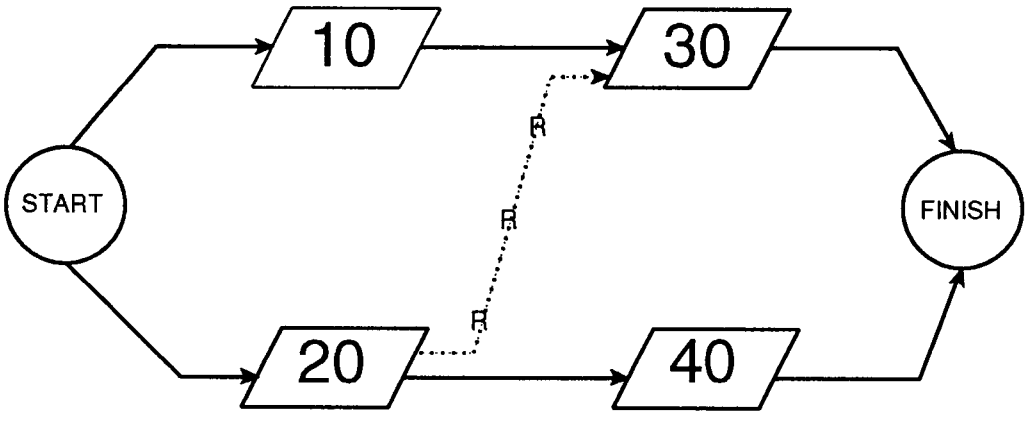


Figure B-3. Resource dummy arrows

The third variation is a deviation from the second priority of step 2 in the resource-constraining process. If a combination of activities provides sufficient resources to meet the constraint and each has plenty of float, delay each of these activities rather than one activity that is critical or nearly critical.

A project manager can use these techniques after he fully understands the basic techniques of resource constraining. For any project with insufficient resources, the project manager must ultimately decide which activities to delay. An understanding of the intricate interaction between each activity will enable the manager to make informed decisions and successfully complete the project.

SAMPLE PROBLEM

As a project supervisor, you developed the logic diagram and ES schedule shown in Figure B-4, page B-6. During your initial planning, the number of available squads (14) was the only critical resource. Later you were tasked to provide three squads to support post cleanup during the same time period. This has reduced the number of squads available for the project to 11. You must resource constrain the project to 11 squads by completing the following tasks:

- Resource constrain the ES schedule (Part 1).
- Update the logic network (Part 2).
- Update the ES schedule (Part 3). Determine if the reduced number of squads will affect the project duration.

PART 1

After constraining the ES schedule, you find that there are two resource delays (R) and one logic delay (L), as shown in Figure B-5, page B-7. Activity 15 cannot start until the resource from activity 20 becomes available. When delayed, activity 15 moves into interfering float. This causes a logic delay of three days for activities 35 and 40. (Activity 45 is unaffected.) When time period 6 is constrained, you find that activity 40 must be delayed one additional day for insufficient resources. Although activity 40 was initially delayed due to logic, it will receive an "R" delay. The resource needed for activity 40 must come from activity 30.

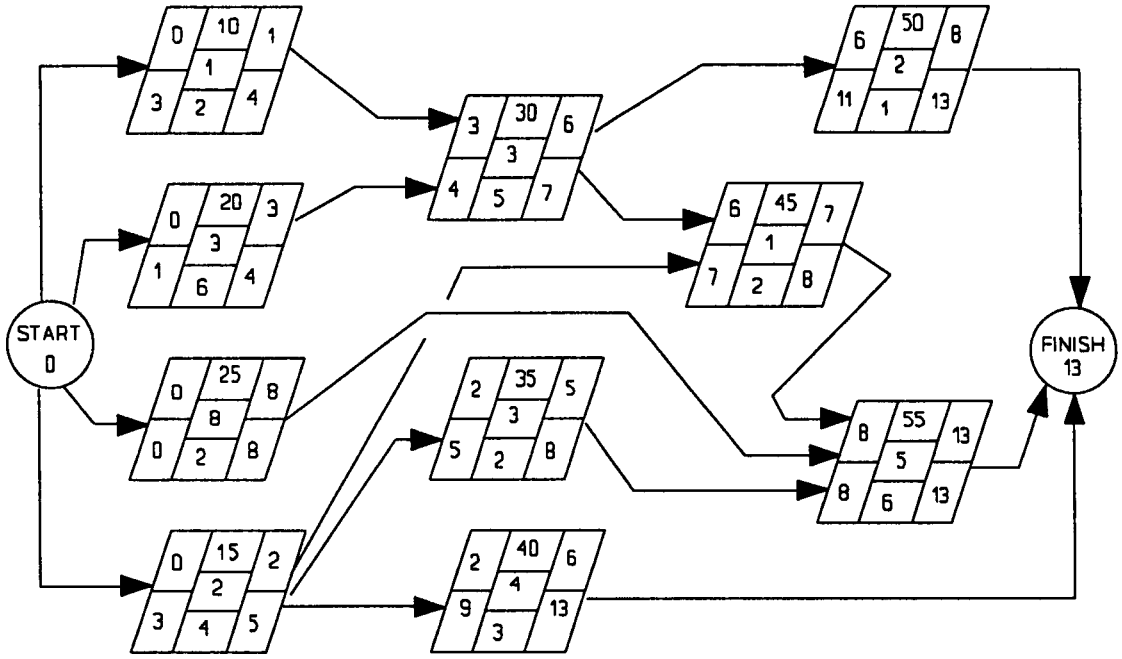
PART 2

The two resource flow arrows are incorporated into the logic network by drawing dashed arrows and a superimposed "R", as shown in Figure B-6, page B-7. This establishes two new paths in the network and changes the time analysis. Whereas the old critical path consisted of nodes 25 and 55, there is now an additional critical path consisting of nodes 20, 15, 35, and 55.

PART 3

A new ES schedule must incorporate the changes which were made in the logic network. After updating the activity numbers (step 10), time frames (step 11), and float calculations (step 12), you prepared an ES schedule as shown in Figure B-7, page B-8. Activities 20 and 30 changed follow-on activities. Time frames (ES and/or LF) changed for activities 15, 20, 35, and 40. Interfering float calculations, however, did **not** change for the activities with float (activities 10, 30, 40, 45, and 55).

You have now constrained the resources for this project. Three additional activities (15, 20, and 35) have become critical. None of the changes resulted in any activity being delayed beyond its LF (right bracket). Therefore, the project duration will not change.



NETWORK NUMBER	EARLY START SCHEDULE																	
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
10(30)	2s			X														
15(35,40,45)	4s	4s	X	X	X													
20(30)	6s	6s	6s	X														
25(55)	2s	2s	2s	2s	2s	2s	2s	2s										
30(45,50)				5s	5s	5s	X											
35(55)			2s	2s	2s													
40			3s	3s	3s	3s												
45(55)							2s											
50							1s	1s										
55									6s	6s	6s	6s	6s					
Squads(S)	14	12	13	12	12	10	5	3	6	6	6	6	6					

Figure B-4. Sample problem

NETWORK NUMBER	EARLY START SCHEDULE																	
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
10(30)	2S																	
15(35,40,45)				4S	4S	R												
20(30)	6S	6S	6S	X														
25(55)	2S	2S	2S	2S	2S	2S	2S	2S										
30(45,50)				5S	5S	5S	X											
35(55)						2S	2S	2S	L									
40							3S	3S	3S	3S				R				
45(55)							2S											
50							1S	1S										
55									6S	6S	6S	6S	6S					
Squads(S)	~~14~~	~~12~~	~~13~~	~~12~~	~~12~~	~~10~~	~~5~~	~~3~~	~~6~~	~~6~~	6	6	6					
	10	8	8	11	11	9	10	8	9	9								

Figure B-5. Resource-constrained early start schedule

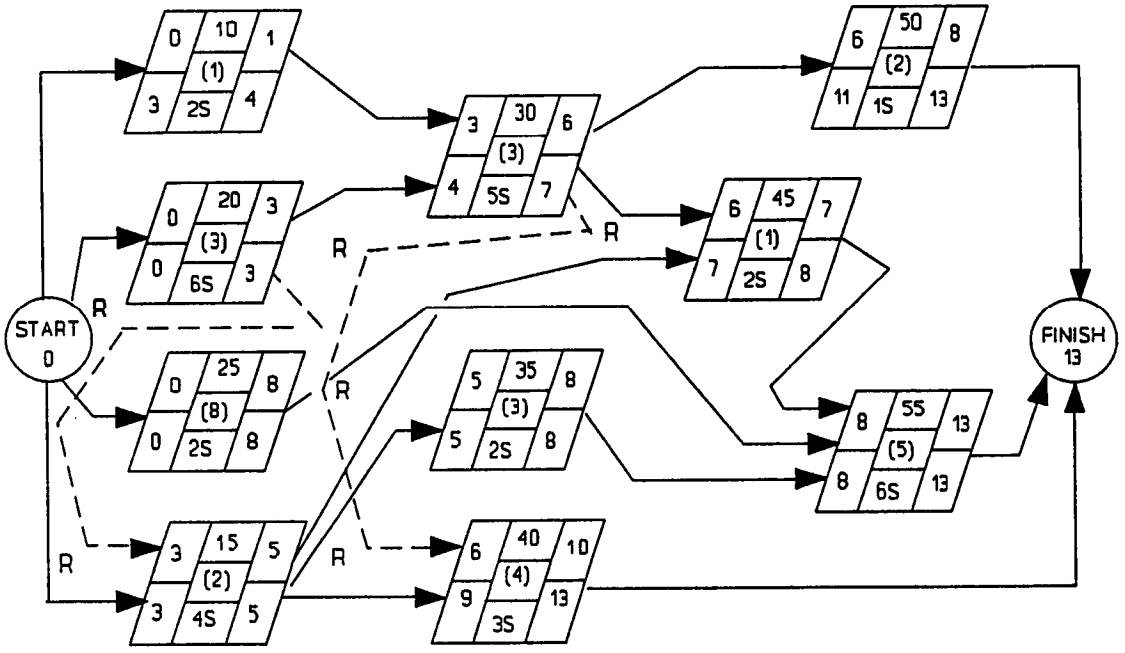


Figure B-6. Updated logic network

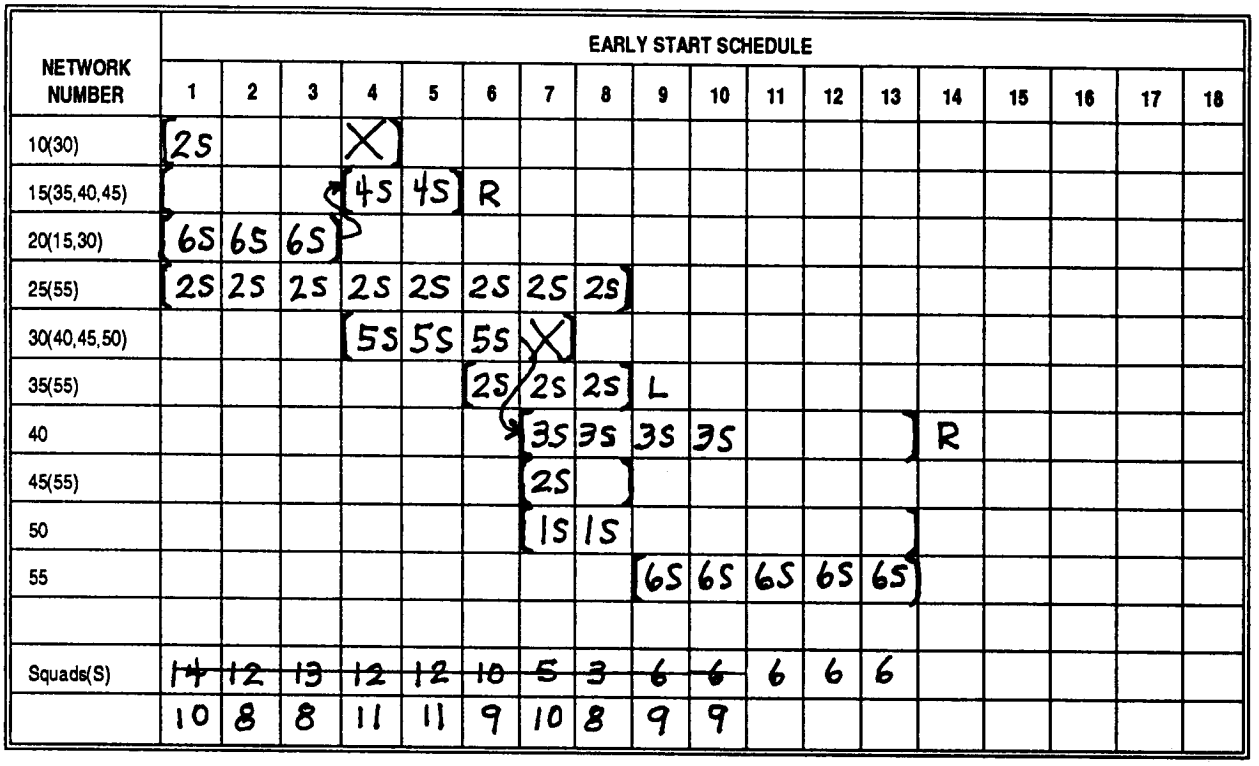


Figure B-7. Updated early start schedule

USE OF COMPUTERS

Off-the-shelf project management software is available which will automatically constrain or cross-level resources. However, in order to market this software to a broad spectrum of users, the programs generally use criteria to resource constrain that is not acceptable for military construction where the highest priority is usually to avoid extending the overall project duration. It is highly recommended that military managers manually use the 12-step constraining process listed above, even when using a computer program.